Chapter 7
Lamps: A Test Problem for Cooperative Coevolution

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Abstract. We present an analysis of the behaviour of Cooperative Co-evolution algorithms (CCEAs) on a simple test problem, that is the optimal placement of a set of lamps in a square room, for various problems sizes. Cooperative Co-evolution makes it possible to exploit more efficiently the artificial Darwinism scheme, as soon as it is possible to turn the optimisation problem into a co-evolution of inter-dependent sub-parts of the searched solution. We show here how two cooperative strategies, Group Evolution (GE) and Parisian Evolution (PE) can be built for the lamps problem. An experimental analysis then compares a classical evolution to GE and PE, and analyses their behaviour with respect to scale.

7.1 Introduction

Cooperative co-evolution algorithms (CCEAs) share common characteristics with standard artificial Darwinism-based methods, i.e. Evolutionary Algorithms (EAs), but with additional components that aim at implementing collective capabilities. For optimisation purpose, CCEAs are based on a specific formulation of the problem where various inter- or intra-population interaction mechanisms occur. Usually,
these techniques are efficient as optimiser when the problem can be split into smaller interdependent subproblems. The computational effort is then distributed onto the evolution of smaller elements of similar or different nature, that aggregates to build a global solution.

Cooperative co-evolution is increasingly becoming the basis of successful applications [1, 6, 8, 15, 19], including learning problems, see for instance [3]. These approaches can be shared into two main categories: co-evolution process that happens between a fixed number of separate populations [5, 13, 14] or within a single population [7, 10, 18].

The design and fine tuning of such algorithms remain however difficult and strongly problem dependent. A critical question is the design of simple test problem for CCEAs, for benchmarking purpose. A first test-problem based on Royal Road Functions has been proposed in [12]. We propose here another simple problem, the Lamps problem, for which various instances of increasing complexity can be generated, according to a single ratio parameter. We show below how two CCEAs can be designed and compared against a classical approach, with a special focus on scalability.

The paper is organised as follows: the Lamps problem is described in Section 7.2 then the design of two cooperative co-evolution strategies, Parisian Evolution and Group Evolution, is detailed in Sections 7.3 and 7.4. The experimental setup is described in Section 7.5: three strategies are tested, a classical genetic programming approach, (CE for Classical Evolution), the Group Evolution (GE) and the Parisian Evolution (PE). All methods are implemented using the μGP toolkit [16]. Results are presented and analysed in Section 7.6 and conclusions and future work are given in Section 7.7.

7.2 The Lamps problem

The optimisation problem chosen to test cooperative coevolution algorithms requires to find the best placement for a set of lamps, so that a target area is fully brightened with light. The minimal number of lamps needed is unknown, and heavily depends on the topology of the area. All lamps are alike, modeled as circles, and each one may be evaluated separately with respect to the final goal. In the example, the optimal solution requires 4 lamps (Figure 7.1 left): interestingly, when examined independently, all lamps in the solution waste a certain amount of light outside the target area. However, if one of the lamps is positioned to avoid this undesired effect, it becomes impossible to lighten the remaining area with the three lamps left (Figure 7.1 right). Since lamps are simply modeled as circles, the problem may also be seen as using the circles to completely cover the underlying area, as efficiently as possible.

This apparently simple benchmark exemplifies a common situation in real-world applications: many problems have an optimal solution composed of a set of homogeneous elements, whose individual contribution to the main solution can be evaluated